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13. ABSTRACT (Maximum 200 words)

In a series of papers, we have proven new, fundamental rigorous results about the critical behavior of percolation models. In the discrete case, for a hierarchical model of the conducting backbone, we have proven inequalities on the critical exponent for the conductivity of the random resistor network. Our inequality less than or equal to 2 in three dimensions rules out roughly one fourth of the numerical estimates published over the last 25 years.

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Title: Macroscopic Properties of Random and Quasiperiodic Media

Period: 4/1/90 to 7/31/92

PI: Kenneth Golden, Princeton University
(Currently at U. of Utah)

RESULTS

Percolation models play a fundamental role in the analysis of the transport properties of a wide variety of both natural and man-made materials in science and engineering. Models such as the discrete random resistor network and the continuous random checkerboard capture the essential features of many systems where percolation effects dominate, yet lend themselves to rigorous mathematical analysis. Media represented by these models include semiconductors, cermets, thermistors, thick-film resistors, superconducting composites, and porous media.

percolation

In a series of papers, we have proven new, fundamental rigorous results about the critical behavior of ~~these~~ models. In the discrete case, for a hierarchical model of the conducting backbone, we have proven inequalities on the critical exponent t for the conductivity of the random resistor network [1,2]. Our inequality $t \leq 2$ in three dimensions rules out roughly one fourth of the numerical estimates published over the last 25 years. For the classical continuous random checkerboard model in two dimensions with conductors 1 and δ in proportions p and $1-p$, it has been known since the 1960's via Keller duality that the effective conductivity σ^* obeys $\sigma^* = \sqrt{\delta}$ at $p = 1/2$. We have discovered the surprising result [3] that this $\sqrt{\delta}$ is exact to leading order as $\delta \to 0$ for p throughout the interval $(1-p_c, p_c)$, where p_c is the site percolation probability, i.e., $\sigma^* = \sqrt{\delta} + 0(\delta)$ as $\delta \to 0$ for $p \in (1-p_c, p_c)$. Finally, we have developed a generalization of this checkerboard model which represents the behavior of porous media with complex, self similar microstructure, or of certain types of superconducting composites, and obtained rigorous results on its transport properties near criticality [4].

less than or equal to

Currently we are in the process of writing an invited article to review the above work on percolating systems [5].

In other work, we wrote a review article on transport in quasiperiodic media, in which we applied some of our previous results on classical transport to quantum transport problems in such media [6]. This past summer, while visiting the University of Toulon, we began discussing further applications of these ideas in the quantum domain. In the area of bounds on complex transport coefficients for multicomponent materials we found new symmetric representation formulas for the coefficients [7], and this past summer began trying to extend this work with my Ph.D. student.

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